TAMDAR Architectures

Weather Accident Prevention Annual Project Review
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The Johns Hopkins University
Applied Physics Laboratory
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NASA Glenn Research Center

Outline

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- TAMDAR Mission
- TAMDAR Requirements
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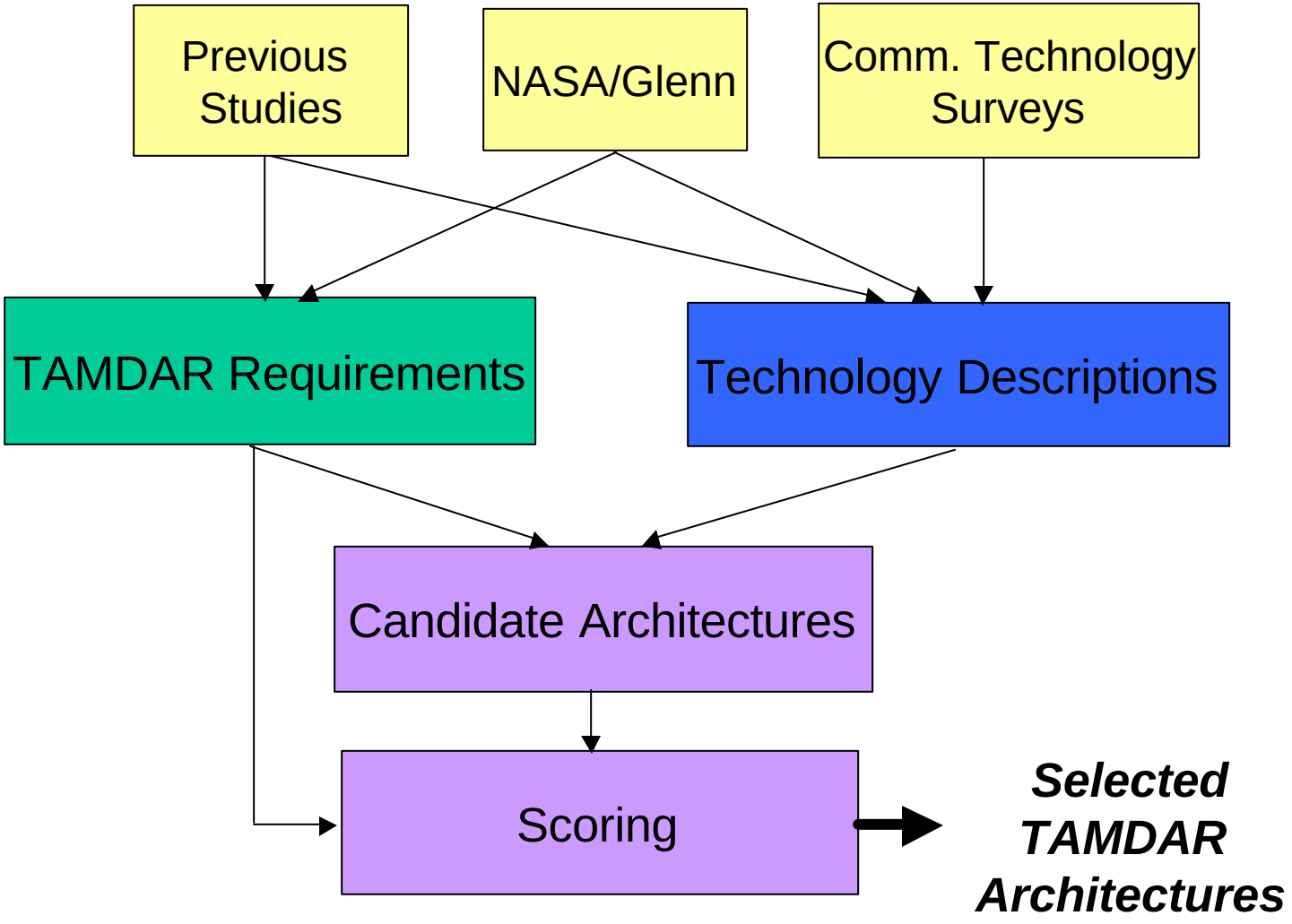
Project Background

- APL is conducting communications architecture and modeling/simulation (M&S) work sponsored by the NASA Glenn Research Center (GRC)
  - Architecture work is focused on two aviation applications:
    - Flight Information Services (FIS)
    - Tropospheric Airborne Meteorological Data Reporting (TAMDAR)
  - M&S work is focused on Automated Dependent Surveillance - Broadcast (ADS-B) links
- TAMDAR architecture study was a collaboration between NASA GRC, APL and Lockheed Martin (as a GRC support contractor)

Architecture Analysis Process



TAMDAR Mission

- To enable weather data collection from aircraft operating at lower altitudes to facilitate improved weather forecasting
- Targeted for GA and regional aircraft
  - Complements other systems like the Meteorological Data Collection and Reporting Service (MDCRS)
  - Content: wind, temperature, moisture, turbulence, icing, etc.
- Focus of architecture study is on communications
  - TAMDAR sensor and processors are other key aspects of the system
  - Near-term deployment (2003) is a goal of the study

TAMDAR Requirements

- Requirements were examined in the following areas:
  - Air-to-Ground Channel Capacity
  - Air-to-Air Channel Capacity
  - Spectrum/Deployment
  - Platform Constraints
  - Coverage
  - Link Availability
  - Latency
  - Cost
  - Infrastructure
- Various sources were used to derive estimates (as will be cited)

Air-to-Ground Capacity (1 of 2)

TAMDAR Requirements

- Capacity is based on message size and frequency of transmission
- Table developed by NASA/Glenn
- Overhead (20%) is added to account for framing, error detection, reserve content, etc.
- Message size is 250 bits

Element	Bits
I.D.	16
A/C Type	8
Date/Time	
Date	16
Time	20
Location	
Latitute	20
Longitude	20
Pressure Altitude	16
Weather Elements	
Wind	
Speed	8
Direction	8
Temperature	12
Moisture	
Humidity	8
Water Vapor Mixing Ratio	8
Peak Liquid Water Content	8
Average Liquid Water Content	8
Super Cooled Large Droplet	4
Turbulence	
Average	8
Peak	8
Icing	4
Roll Angle	4
Phase of Flight	4
Total	208

Air-to-Ground Capacity (2 of 2)

TAMDAR Requirements

- Frequency of transmission is based on D0-237 estimates for AUTOMET
  - Takeoff: 1 report per 6 seconds
  - Climb/Descent: 1 report per 20 seconds
  - Cruise: 1 report per 15 minutes
- *Average* Capacity is then derived:
  - Takeoff: 42 bps
  - Climb/Descent: 12.5 bps
  - Cruise: 0.28 bps
- Note, this does not assume a bundled transmission scheme

Air-to-Air Capacity

TAMDAR Requirements

- Determination of air-to-air capacity (at receiver) is difficult
  - Requires knowledge of the "radius of interest" for TAMDAR reports
  - Communications and processing complexity significantly higher than a pure downlink configuration
  - May enhance business case for TAMDAR adoption
- Based on estimates of the number of aircraft in the radius of interest (about 100 nm) in each flight phase, an aggregate capacity is estimated at 2-3 kbps

Spectrum/Deployment and Infrastructure

TAMDAR Requirements

- Constraint of study was on near-term implementation in 2003
  - Spectrum filings would need to be completed
  - Deployment of hardware would need to be in-progress
- Infrastructure needed for collection of TAMDAR reports at national repository
  - Mechanism would vary based on architecture
  - Terrestrial LOS systems would require an infrastructure with terrestrial network connectivity to be viable
  - SATCOM systems may support direct feed to a national repository

Platform Constraints and Cost

TAMDAR Requirements

- Study mostly focused on GA/regional aircraft
- General desire for adoption of aviation weather systems on-board GA is established
- TAMDAR is a more complex business case than other weather provisions (e.g., FIS-DL)
  - User is providing data to improve national forecasting
  - Air-to-air transfers are potentially the stronger business case
- Old Dominion University TAMDAR study
  - 67% of pilots would pay less than $2000 for TAMDAR system and only 17% would pay more than $4000 (NRE)
  - Assume minimum recurring cost; subsidies may be a potential means of supporting capability

Coverage and Link Availability

TAMDAR Requirements

- CONUS coverage was requirement for study
- Link availability required to be 99% based on NAS priority levels
  - TAMDAR assumed to be "routine service"
  - NAS Levels:
    - Critical Services: Loss would prevent safe operation and control of the aircraft. Availability goal of 0.99999 and service restoration time of 6 seconds.
    - Essential Services: Loss would reduce capability for safe operation and control of the aircraft. Availability goal of 0.999 and service restoration time of 10 minutes.
    - Routine Services: Loss would cause no significant reduction in the capability for safe operation and control the aircraft. Availability goal of 0.99 and service restoration time of 1.68 hours.

Latency

TAMDAR Requirements

- 1-minute latency used in study
- Latency affects *instantaneous* capacity
  - Average capacity in cruise is 0.28 bps (15 minute period)
  - Delivery of message in 1 minute will require 4.2 bps instantaneous rate

Summary TAMDAR Requirements

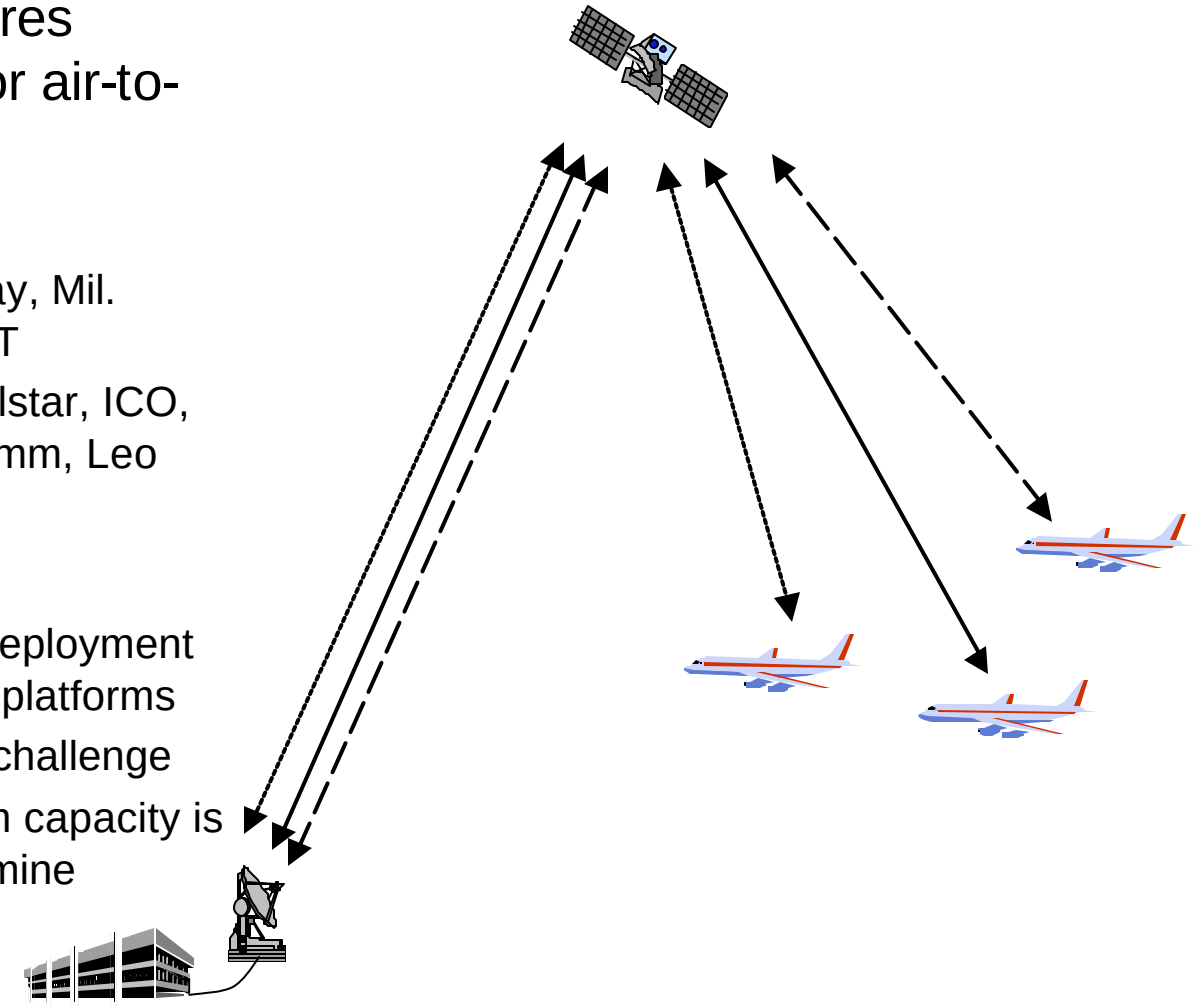
Air-to-Ground Channel Capacity	transmit: 4.2 bps - 42 bps
Air-to-Air Channel Capacity	transmit: 4.2 bps - 42 bps receive: ~2-3 kbps
Spectrum/Deployment	System operational by 2003
Platform Constraints	Appropriate for GA/regional aircraft
Coverage	CONUS
Link Availability	99%
Latency	1 minute
Cost	Under $5000 NRE; minimum recurring
Infrastructure	Support data transfer to CONUS repository

Architecture Scoring Methodology

- Capacity (air-to-ground; air-to-air) and spectrum/deployment are treated as first-pass threshold requirements
- Other requirements provide gradations
- Scores assigned at several levels:
  - System architecture meets requirement with significant margin
  - System architecture meets requirement
  - System does not meet requirement
- In some cases, inadequate information was available and a neutral score was assigned

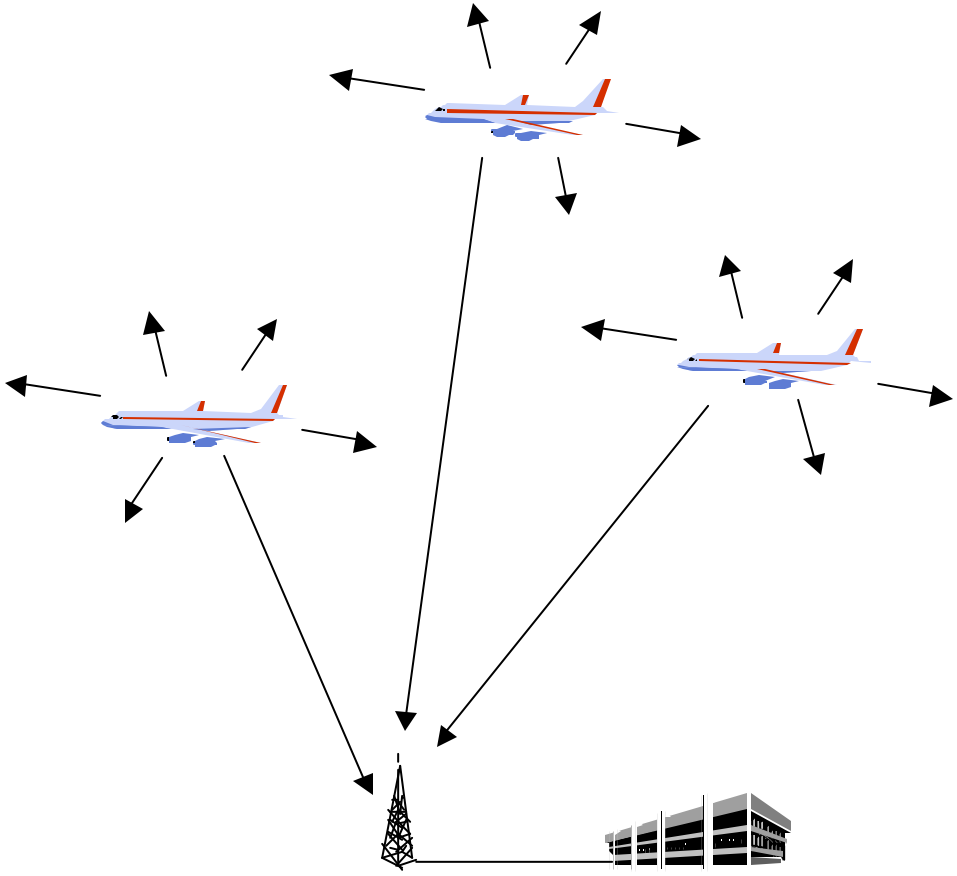
Satellite

- Two potential architectures (differing in technique for air-to-air transfers)
- Systems considered:
  - GEO: Inmarsat, Spaceway, Mil. UHF/SHF, S-DARS, eSAT
  - Non-GEO: Iridium, Globalstar, ICO, Ellipso, Teledesic, Orbcomm, Leo One, Final Analysis
- Preliminary findings:
  - Primary discriminator is deployment and existence of aviation platforms
  - Air-to-air messaging is a challenge
  - Store-and-forward system capacity is critical capability to determine



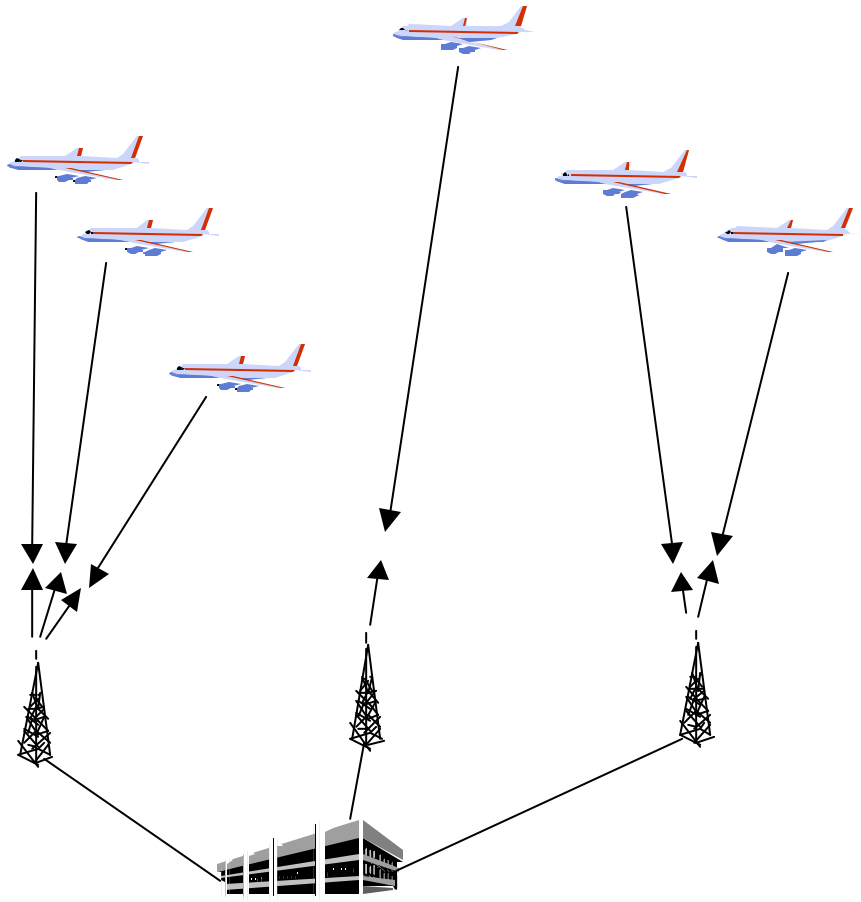
Terrestrial: Broadcast

- Systems considered: VDL Mode 4, 1090 Extended Squitter, UAT, GATElink, DARC
- Preliminary findings:
  - Main strength is ability to achieve air-to-ground and air-to-air capacity without significant reconfiguration
  - Potential drawback is the cost/schedule for installation of receivers



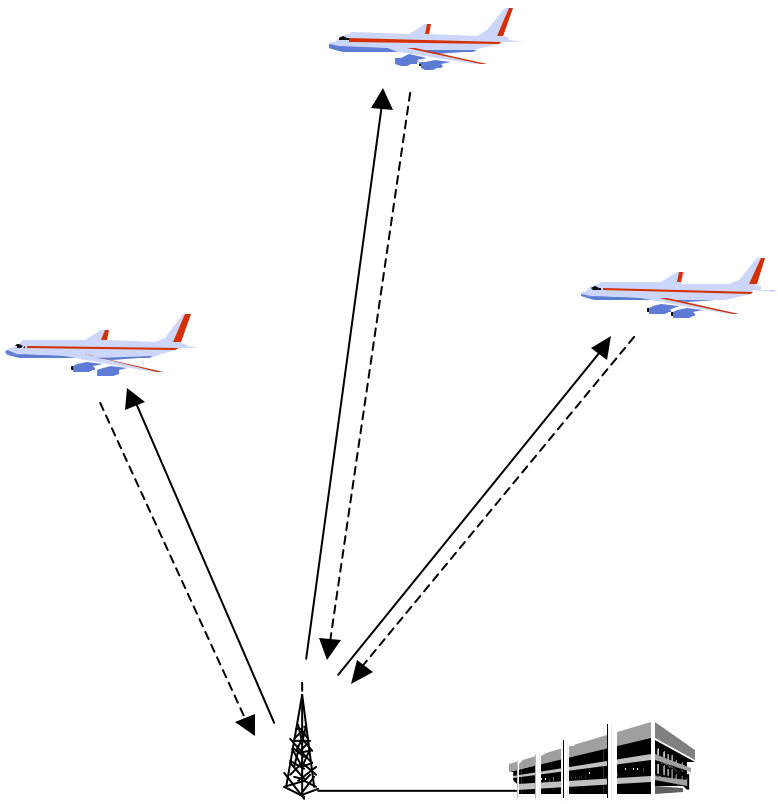
Terrestrial: Cellular

- Systems considered: Aircell, MagnaStar, 3G/4G cellular, Mobitex
- Preliminary findings:
  - Massive commercial investment is strong benefit
  - Air-to-air requirement is a potential challenge
  - Cellular antenna coverage at desired altitudes should be investigated further



Terrestrial: Addressable

- Systems considered: HFDL, VDL Mode 2, VDL Mode 3, ACARS, AAN
- Preliminary findings:
  - Current deployment of infrastructure and aviation platforms is a benefit
  - Potential drawback with regard to traffic loading
  - Air-to-air requirement is a potential challenge



Hybrids

- Hybrids were not found to create effective solutions for the near term
- No clean marriage of strengths and weaknesses
  - SATCOM air-to-air capacity challenge could be compensated with an ADS-B link (for which air-to-air capacity is a strength)
  - However, complete ADS-B link deployment is challenge for 2003
- Combined cost is also a significant issue
- Hybrids could also be considered across FIS and TAMDAR

Summary

- Preliminary communications architecture study conducted for near-term deployment of TAMDAR
- Requirements developed and satellite/terrestrial approaches considered
- Refinement of scoring and inclusion of other links is underway